Whole Building Energy Efficiency: A Long but Fruitful "Row to Hoe"

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INTRODUCTION

Whole building energy efficiency is an interesting idea in an industry that sometimes seems mesmerized by a myriad of competing technologies. Ideally, whole building energy efficiency would mean that *all* the energy using systems in a building would be optimized in terms of their own design energy requirements, optimized in terms of the way they were operated, and optimized in terms of how they are integrated with other building systems.

Theoretically, the perfect time to do all this is when the building is being designed in the first place. However, given the pace of new construction during the past decade, the buildings that really count (and are the focus of our consultancy) are the *existing* buildings, not the ones yet to be built or are in the process of being built. Because existing buildings represent a "dirty" rather than a "clean sheet of paper," they represent a truly unique challenge for the energy engineer and the energy retrofit contractor.

Energy Resource Associates, Inc. is in a unique position to comment on the subject of whole building energy efficiency. The history of the firm includes the development and start-up of energy services firms, providing investigation, design and commissioning services to energy services companies, the development of energy management programs and strategies for building owners with large real estate portfolios, expert witness services for energy services companies, building owners and utility companies, development of building and technology-specific energy retrofit projects for building owners, monitoring and evaluation of energy retrofit and demand-side management programs, and design and management of energy-related projects including lighting fixture retrofit, lighting control, HVAC retrofit, building automation and digital controls (including commissioning), central cooling plant upgrades and cogeneration.

WHAT DOES IT TAKE TO MAKE AN EXISTING BUILDING EFFICIENT?

Based on our decades of experience in the energy engineering business, we have come to understand that it takes two things to achieve energy efficiency. The first of these is energy efficiency technologies - devices, equipment, systems and concepts that allow an energy using system *or an end use* to operate using less energy. The other thing is even more important, though, and is the process by which the energy efficiency is achieved. By "process" we mean the steps which are taken, many technical and many non-technical, which allow an organization to proceed down the path to energy efficiency. While finding the appropriate technologies and putting them in place is difficult enough, the process is fraught with opportunities for going astray.

Technologies

There are numerous technologies that can serve to make a building operate more efficiently. Perhaps even more important is the fact that energy efficiency technologies are constantly evolving and developing, meaning that a building retrofitted 5 years ago, may be ready for another retrofit today! Among the technologies commonly employed are:

- *Lighting fixture retrofit.* This includes installing new light sources in existing fixtures, replacing the fixture lens with a better lens/diffuser, installing new fixtures or even converting the entire type/concept of the lighting being used (e.g., converting a luminous lobby ceiling to pendant-mount "architectural" lighting to both improve the actual light being delivered and the appearance of the space).

- *Lighting control.* This might include using a building automation system to periodically "sweep" lights off in a building (using powerline carrier, low voltage or power-sensing wall switches), local occupancy controls, lumen-maintenance controls, or, most likely, a combination. Lighting control paybacks can look bad if fixture retrofit is assumed to be implemented first (since the fixture retrofit will therefore effectively be "skimming the cream,") so looking at fixture retrofit and control as a single retrofit is sometimes advisable.

- *Air handling and distribution.* The obvious retrofit to most air handling systems is conversion to variable volume. Unfortunately many conversions are conceived using extensive air distribution system retrofit including new pressure-independent terminal boxes, etc., which often pushes the cost beyond a reasonable payback. Creative retrofit means finding an effective way to modify the existing terminal with minimum ductwork disruption and minimum use of new equipment. While minimum airflows and pressure-independence are important concerns, overly conservative engineering has "killed" many worthy projects. In our experience prototyping a retrofit in the field or conducting whole-building trials are often needed to prove feasibility and installability, though this practice is rare in the industry and requires a unique blending of product engineering, system design engineering, building operations, and contracting skills. A unique variation on variable volume is what we refer to as ™*Incremental Constant Volume* and is applicable to spaces such as hospitals where the airflow cannot be allowed to vary on a continuous basis, but can be periodically reset to different "incremental" levels of constant volume, based on occupancy of the space or perhaps ambient conditions. Reducing the airflow in an operating room from 20 air changes per hour (when occupied) to 10 air changes per hour (when unoccupied), for example, has the potential to reap huge benefits. Another fairly obvious air handling retrofit is the addition of outside air economizer capability. An amazing number of buildings are still not so equipped, or were provided with economizers which did not work for reasons such as insufficient relief capability. It is little known for instance, that an outside air economizer pressurizing a building to more than about 0.05" W.G. can result in pushing open automatic building entry doors (which have been properly adjusted to comply with handicap access codes) and thus disabling the building security system (if installed), and, in turn, possibly causing the outside air economizer to have to be disabled as a result. Yes, *all* these issues are inexorably intertwined!

- *Central heating and cooling and distribution.* Energy efficient technologies here include replacement of equipment with more modern and efficient equipment (chillers today are 30% to 50% more efficient than those of 20-30 years ago), optimization of the plant's operation (auxiliaries often use more energy than the prime movers at low load conditions and warrant particular examination) and, similar to air-handling systems, conversion to variable flow. Even single-loop chilled water systems, for example, have been successfully converted to variable flow!

- *Automation and digital controls.* While such systems may very well have been oversold by their vendors in the past, the truth is, once the gross inefficiencies are eliminated, optimization of the use of the building's systems, particularly HVAC, is one of the final frontiers of energy efficiency. Digital controls can be uniquely effective because they don't embody fixed concepts of system operation, but are as flexible and as innovative as the technician in charge of their operation.

- *System re-configuration.* Frequently the entire concept of the energy-using system is an unfortunate mismatch with the end use. For example, an entire central cooling plant may be kept in operation to serve a small cooling end-use, or multiple central plants may have been built as part of an expansion program, where a single, integrated plant would use less energy. Figure 1 shows, for example, a schematic of a chilled water plant which consists of two plants which have been integrated through the installation of an interconnecting pipeline (with transfer pump) and where the older of the plants has been renewed with high- efficiency chillers and converted to variable flow (in this case a dual-loop system). Through the use of a building automation system, these two plants are operated as though they are a single plant.

- *Fuel switching.* While really not an efficiency technology, *per se*, technologies such as thermal storage, cogeneration, absorption, engine-driven chillers and the like, are the real final frontier of energy management and allow optimizing the *cost* of energy, if not the use. Generally these technologies should be employed only once the inefficiencies are eliminated and they should not be allowed to "mask" inefficiencies by supplying cheaper energy for a wasteful use!

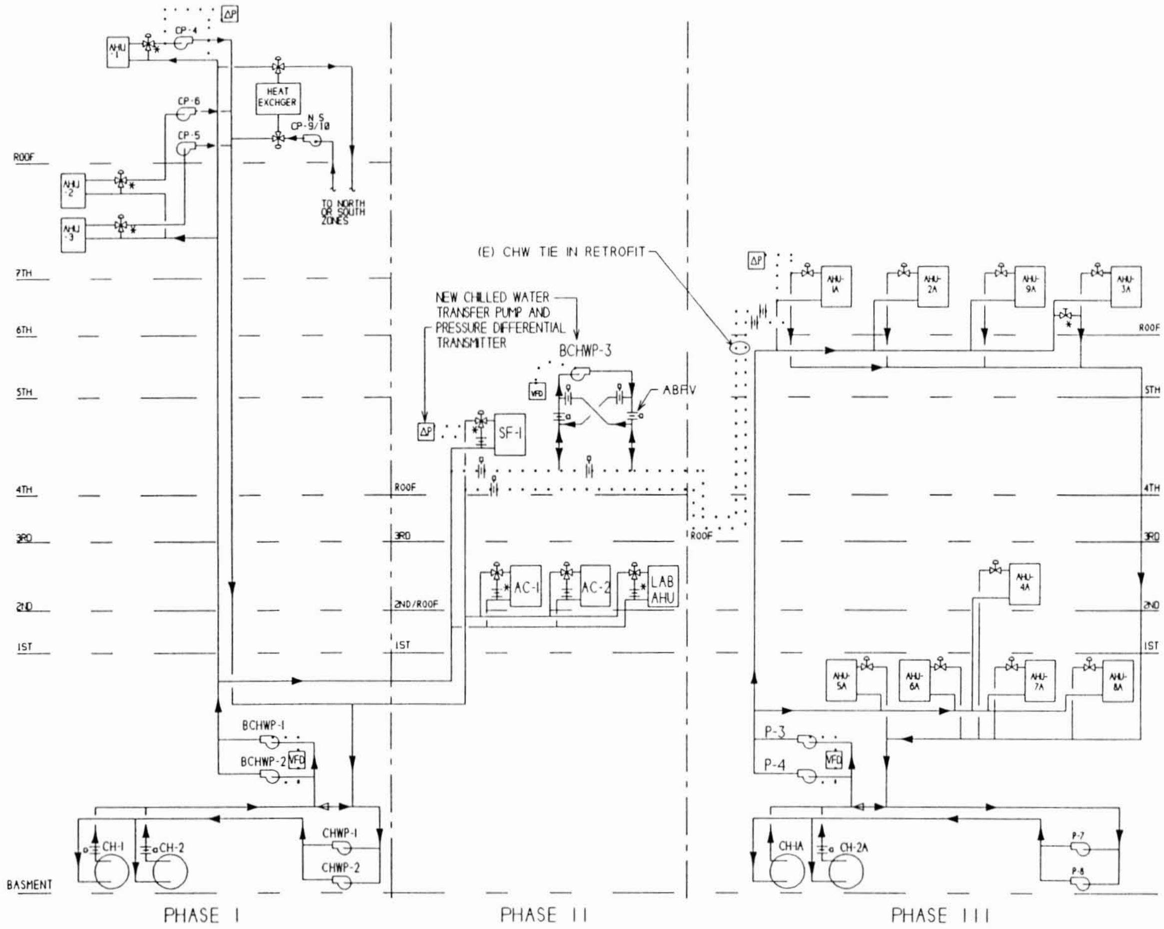

Figure 1. Schematic for Chilled Water System, Including Revisions for New PH-1/2 Chilled Water Plant

The Energy Efficiency "Process"

The process of achieving energy efficiency is, in truth, more critical than the technologies themselves. In a sense, technologies are the "answers" while the process are the "questions." It does little good to have the *right* answer if you asked the *wrong* question. In our experience, energy efficiency projects get in trouble mostly because no one took the time to ask the right questions. The process ought to look something like the following:

- *Energy accounting.* Even a trip around the earth must start with one step. In energy efficiency, the first step is a careful accounting of all the uses of energy, evaluating the facility's energy use trends over time and comparing the facility to other similar facilities by means of energy use and energy cost indexes. For example, Figure 2 shows a graphic comparison of a group of Northern California hospitals. Once this step is complete, even a relative neophyte can spot the facility with lots of room for improvement.

- *Policy & planning.* While staff may think that energy retrofit is a "no-brainer," management may view the concept as very nebulous

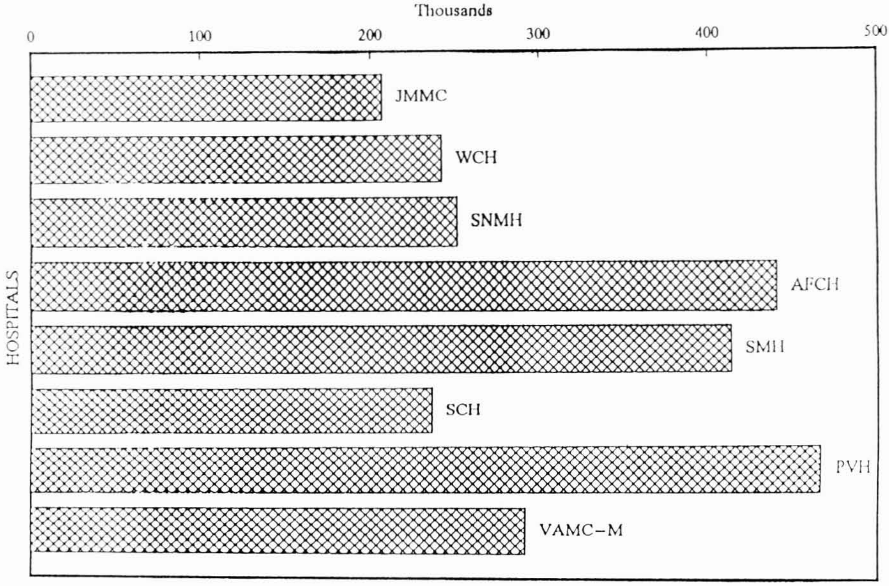

Figure 2. Hospital Comparison—Btu/SqFt/Yr—Thousands

and uncertain. Time and energy must be spent informing and educating the decision makers as to the importance of energy efficiency in enhancing the overall competitiveness of the organization and the dependable nature (properly implemented) of the savings to be produced. It is also critical to convey the idea that to do nothing is not a "zero risk" alternative, as most buildings experience upward "creep" in their energy use and energy rates can generally be depended upon to escalate, meaning that total energy costs will rise if nothing is done to avoid it.

- *Implementation strategy.* Generally there are two ways to go these days, "home-grown-tomatoes," or "store-bought." By these we mean programs which are developed and managed by the in-house staff assisted by engineers and contractors, or programs which are developed and managed by a third party (usually an Energy Services Company, or "ESCo"). While the turnkey approach can be very enticing, building owners should be aware that those most in need of a good turnkey program are also those most vulnerable to a poorly done turnkey program and that ignorance is not bliss. Figures 3 and 4 show the results of two energy retrofit programs which were third-party financed, guaranteed and implemented. As can be seen, one program clearly reduced energy use, while the other resulted in no reduction at all! The experience shown in Figure 4 can be avoided if appropriate implementation steps are followed.

- *Implementation steps.* A well implemented program will always include the following steps:
  - Select the project team on the basis of their experience and qualifications. If it's to be an ESCo, don't be mesmerized by the financial underpinnings of the firm, optimistic (and admittedly enticing) savings projections, or a "rosy" sounding guarantee.
  - A detailed feasibility study is *always* required. There is simply no substitute for time spent in the field investigating systems and equipment, time spent in analysis of the building and its energy using systems and time spent performing detailed calculations of the potential energy savings that might be achieved by implementing certain energy conservation mea-

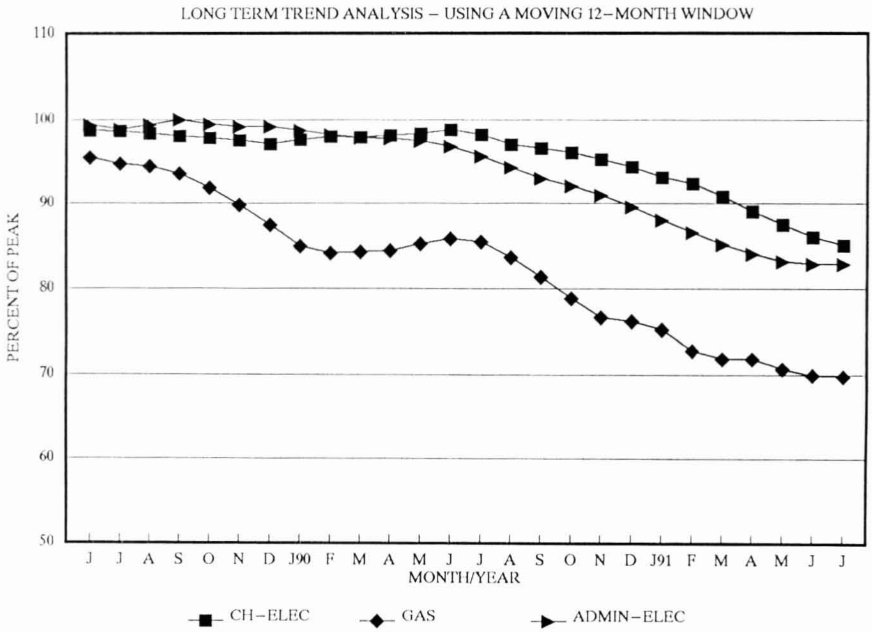

Figure 3. County Courthouse and Administration Building

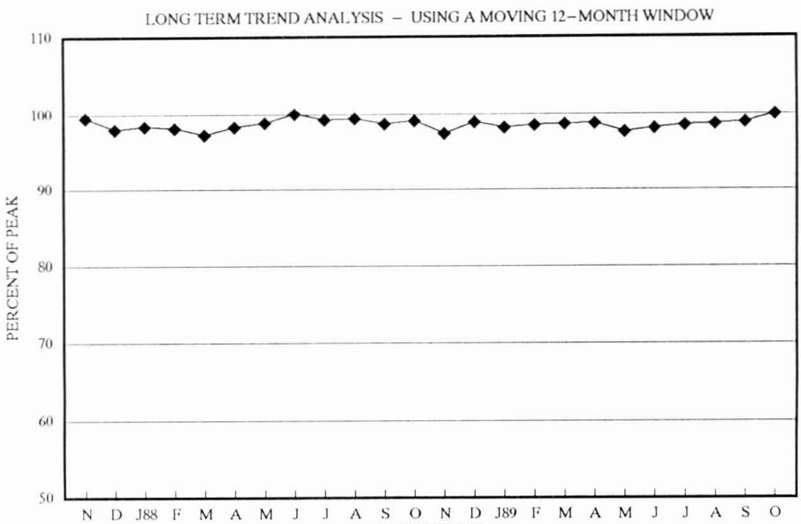

Figure 4. Valley Hospital

sures. Generally speaking, computer simulation or other means to achieve an energy balance, i.e., a totalization of *all* the sources and uses of energy in the facility, is essential. In addition, estimates of savings should "spring-board" out of the comprehensive energy use model so as to prevent double counting or wildly optimistic estimates of savings. As a specific example, if a building only spent $60,000 per year operating its cooling equipment, an estimated annual savings of $50,000 for this function is probably not reasonable, even if the total annual energy bill is $500,000 or more. Each "piece of the pie" must be looked at individually instead of always being considered as a part of the total pie.

— The engineering feasibility study, its source data and the bulk of the assumptions and calculations should be documented for review by all parties.

— The intended energy conservation work should be identified by means of detailed scopes of construction work so that the installing company as well as the buyer can have a "yard stick" by which to measure whether or not the project has actually been implemented.

— Extensive construction documentation should be developed, both to guide the installing contractor's craftsman, but also for the owner to see and concur with the detailed installation work planned, and to use as a troubleshooting tool once the work is complete and/or the energy services contract term has run out.

- *Energy accounting.* Yes, back to the beginning. Some people refer to this as "monitoring and evaluation" and consists of accounting for the avoided costs produced by the project, and possible periodic on-site review of the actual equipment and system functioning (just because it's installed, doesn't mean its actually working!). With energy services contracts, this method intended for tracking cost avoidance should be clearly defined and well documented and implemented in a way that *both* parties can track avoided cost when starting with the same periodically measured source data (unit costs of energy, system operating parameters, equipment run times, etc.).

REAL WORLD RESULTS

The following are thumbnail sketches of three whole building energy efficiency programs, including private and public owners, office building and hospital facilities. It should be noted, that even with a turnkey energy services approach, the total time from the decision to proceed with a program to having all the work done requires a period of approximately two years, or more. While it might be easy to implement a lighting fixture retrofit in a matter of a few calendar months, whole building energy efficiency is another matter altogether. All of the projects described below followed the implementation steps outlined above.

Program No. 1

This program involved the retrofit of a county administration building and courthouse complex. The 350,000-square-foot administration building was built in the late 60's and is relatively modern in terms of its building construction, HVAC, and lighting systems. The 250,000-square-foot courthouse building, by contrast, was built in the 1920's and shows its age in terms of its construction, the wide variety and age of its HVAC systems and the wide variety and age of its lighting systems. Each building was separately supplied with electricity and both buildings share a common central cooling and heating plant.

Through a competitive proposal process, the county choose a team to implement the project. This team consisted of a prime contractor (who was actually a local mechanical service contractor), a consulting engineering and a financier. The steps to project implementation included the following:

The retrofit scope included:

- An energy management computer for time-scheduling of virtually all HVAC equipment
- Modifications to the majority of the air handling systems including direct digital controls, conversion to variable air volume and the addition of outside air economizers on systems not so equipped
- Extensive lighting fixture retrofit

The results of this program (through Phase-1 only) can be seen in Figure 3 (note that we frequently utilize 12-month-long totals to neutralize seasonal effects in the data so long term trends can be more easily observed).

Program No. 2

This program involved an acute care community hospital in the high-elevation "gold country" of Northern California. The 107,000-square-foot facility was constructed in 12 different projects over the 60's, 70's and 80's and is relatively modern in terms of most of its building construction, HVAC, and lighting systems. Problems facing this owner included aging equipment, a wide variety of types of systems and equipment, multiple central plants and high energy bills.

The energy efficiency program at this facility includes three phases, one energy services effort, a follow-on in-house effort and a final (in planning) in-house effort. The initial energy services phase was implemented by an ESCo selected from three invited proposals and included:

- Building automation, including digital controls on all air handling systems
- Modifications to most of the air handling systems to provide time and occupancy-controlled airflow reset
- Lighting fixture retrofit
- Lighting controls

The second phase, recently completed, was integrated with a central cooling plant expansion and modernization project and included:

- Installation of a dedicated cooling system with waterside economizer to allow the central plant to no longer have to support a small critical constant load and be shut down
- Replacement of aging, inefficient refrigeration equipment along with an oversized cooling tower
- Conversion of the chilled water system to variable flow
- Integration of three chilled water systems into one

- Automation of the entire cooling operation

The third phase, in planning, will include the installation of packaged cogeneration equipment and possible use of abandoned mine shaft water for air conditioning.

The results of this program (through Phase-1 only) can be seen in Figure 5.

Program No. 3

This program involves an acute care metropolitan hospital in the warm-climate "East-bay" region of Northern California. The 368,000-square-foot facility was constructed in three major phases starting in the 60's, and concluding in 1990 and is generally quite modern in terms of the majority of its building construction, HVAC, and lighting systems. Problems facing this owner also included aging equipment, a wide variety of types of systems and equipment, multiple central plants and high energy bills.

The energy efficiency program at this facility has taken place in a great many in-house phases, based on yearly program funding autho-

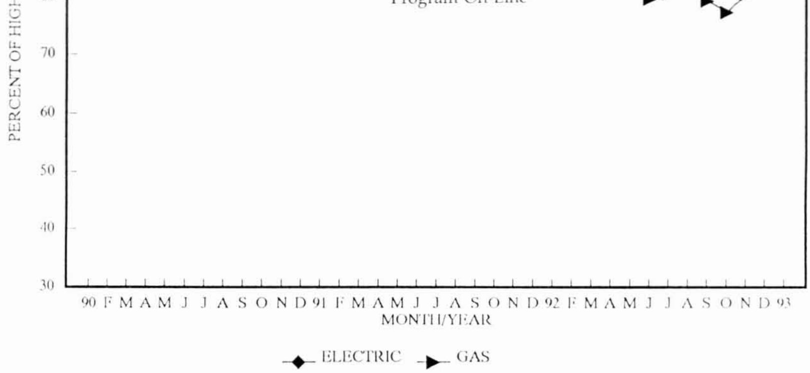

Figure 5. Sierra Nevada Memorial Hospital

rized by management, plus one large central cooling plant modernization project. The annual efforts have been implemented primarily by the owner's preferred engineering firm and hand-picked construction contractors, and has included:

- Expansion of the building automation, to include adding digital controls to virtually all air handling systems
- Modifications to selected air handling systems to provide time and occupancy-controlled airflow reset
- Interconnection of a dedicated computer room system to the central chilled water system for more efficient operation in summer months (when the chilled water plant is in operation)
- Conversion of heating water systems to variable flow
- Lighting fixture retrofit
- Lighting controls
- Cogeneration

The central cooling plant modernization project, currently in construction, included a number of energy efficiency features, including:

- Replacement of aging, inefficient refrigeration equipment along with oversized cooling towers
- Conversion of the chilled water system to variable flow
- Integration of two chilled water systems into one (see Figure 1)
- Automation of the entire cooling operation

Continuing phases will include further air handling system modifications for airflow reset, further refinement and expansion of the building automation system and implementation of new technologies as they become available and economically feasible.

The results of this program (less the effects of the chiller plant modernization) can be seen in Figure 6.

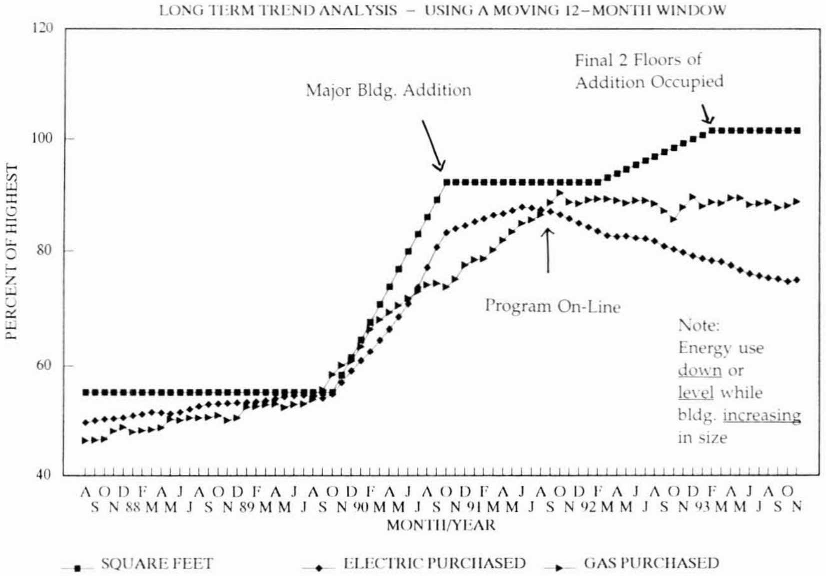

Figure 6. Main Hospital (Phases 1, 2, & 3)

CONCLUSIONS

Total building energy efficiency is a lofty goal, and one not for the weak of constitution as it is more like a trip "around the world" than "around the block." Those building owners who would like to "farm it out" would be well advised to recognize that heavy involvement on their part will still be required. However, most of the technologies available are well proven and only need the commitment of management along with implementation in a deliberate fashion to be successful.

ABOUT THE AUTHOR

James P. Waltz, P.E., President of Energy Resource Associates, Inc., in Livermore, California, is a pioneer in the field of energy management. He has served as energy management program manager for the Air Force Logistics Command and the University of California's Lawrence Livermore National Laboratory. In addition he has worked as an energy management engineer for consulting and contracting firms. In 1981 he

founded Energy Resource Associates for the purpose of helping to shape the then-emerging energy services industry.

Specializing in the mechanical, electrical and control systems of existing buildings, Mr. Waltz's firm has accomplished a wide variety of facilities projects, recently including a corporate-wide energy management program review for a major hospital chain, design of a replacement chilled water plant for a northern California hospital, on-site recommissioning of the entire building automation system for another large northern California hospital and audit and expert testimony relating to a failed energy services contract for a large southern California hospital.

Mr. Waltz's credentials include a bachelors' degree in mechanical engineering, a masters degree in business administration, Professional Engineering Registration in three states, charter member of and Certified Energy Manager of the Association of Energy Engineers (AEE), member of the Association of Energy Services Professionals (AESP), and the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE).

In 1993, Mr. Waltz was elected National Energy Engineer of the Year by the Association of Energy Engineers.